FISHWAYS

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GENERAL PRINCIPLES OF FISHWAY CONSTRUCTION.

With the development in late years of water power for commercial enterprises on an economic basis, with the construction of canals for cheapening the transportation of freight, with the proposition of irrigating the otherwise waste lands of the country—all of which improvements call for the erection of dams across our rivers—the steady decrease of fish life in the waters above said dams or other obstructions has become more and more apparent, and the question has presented itself how to enable the fish to ascend to the headwaters of rivers in order to reach their spawning grounds for the propagation of their kind or to follow their migratory habits in search of food as heretofore. This question is being best met by the construction of suitable fishways.

The underlying principle in the construction of fishways is the retardation of the current velocity of a waterfall so as to enable fish to surmount it. Innumerable devices with that end in view have been invented and proved more or less successful. Certain physical conditions in the location and a proper method of construction are the important factors.

Of the physical conditions, the two principal ones are (1) accessibility of the fishway free from disturbance, its outlet being located in a pool at the bottom of the falls where fish would naturally pass in ascending the river, and (2) an abundant discharge of water through the outlet so as to attract the fish. It is to be noted that fish as a rule do not ascend rivers at low-water stage, but between mean and high water, and preferably during sunshine and warm weather.

In style of construction fishways may be classed in four systems:

I. The inclined plane system, in which a series of baffle or deflecting plates are so arranged in an inclined flume as to cause the water to follow in its descent a long sinuous route.

II. The pool and fall or step system, in which the water is brought down to a lower level by a series of short falls with intervening pools.

III. The counter current system, in which the descending volume of water is being checked by meeting a current opposing it at certain intervals.

IV. The lock and gate system, in which a higher or lower level is reached through one or more locks operated by gates.

In all four systems of fishways certain general rules governing the construction must be observed.

1. The slope of a fishway built on the inclined plane system should not be steeper than 1 foot vertical to 10 feet horizontal; the pool and fall system, as well as the counter current system, should not have a slope of more than 1 vertical to 4 horizontal, so as to insure a current velocity of not exceeding 10 feet per second in any portion of the fishway. The lock and gate system deals merely with a vertical lift. The width of a fishway somewhat governs the slope, and the wider the fishway the more gradual the slope should be.

2. The available volume of water and the size of the fish must be considered in the dimensions adopted for the fishway; small fish, like herring, bass, trout, etc., may not require over 6 inches in the clear at the narrowest points or openings in the fishway, while for large fish, like shad, rockfish, salmon, etc., the clearance spaces should not be less than 9 inches in any direction.

3. A fishway for small fish does not need to be more than 2 feet wide by about 1 foot deep, while that for large fish ought to have a least width of 4 feet with a depth correspondingly large.

4. Plenty of light should be admitted in a fishway, both for maintaining therein the natural conditions of the water, and in order that the interior may easily be inspected and any foreign matter removed.

5. A fishway in all its parts should, by the action of the current of water passing through it, be as nearly as possible self-cleaning of all sand, gravel, mud, and rubbish.

6. The water supply of a fishway should be ample and the same, or nearly so, at both ordinary high and low water stages, avoiding thereby any regulating gates or other devices calling for the services of an attendant.

7. The top and sides of a fishway should be above ordinary high water.

8. The fishway should be built very strong and be well protected against the destructive effects of freshets, drift logs, ice, etc.

9. The intake and outlet should be well submerged and the former protected against floating débris, etc., by a suitable grating.

The location of a fishway must be such that ascending fish will not be alarmed and driven off by disturbance from boats, fishermen, etc.

The material of fishways may be wood, stone, concrete, or iron, depending upon the construction of the dam, its size, the topography and nature of the site, the labor and material at hand, and the funds available.

VARIOUS FISHWAY DESIGNS.

I. INCLINED PLANE SYSTEM.

Figures 1 to 11 show a more or less sinuous course for the water current down an inclined plane, to retard the current velocity.

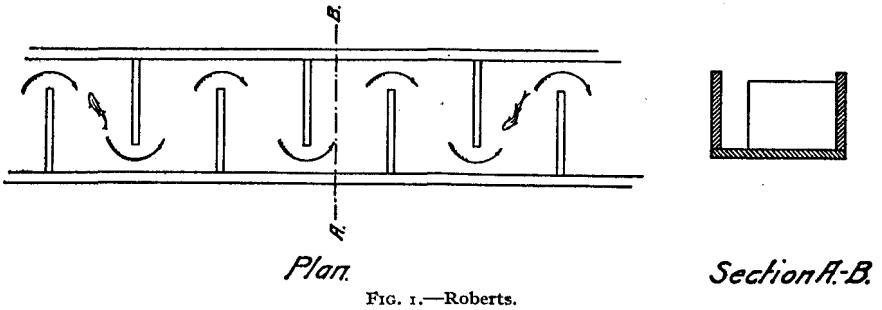


FIG. 1.—Roberts.

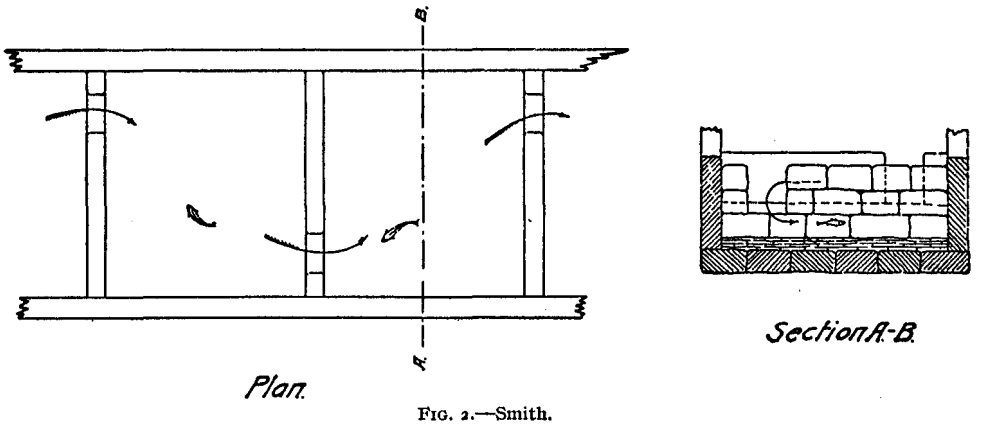


FIG. 2.—Smith.

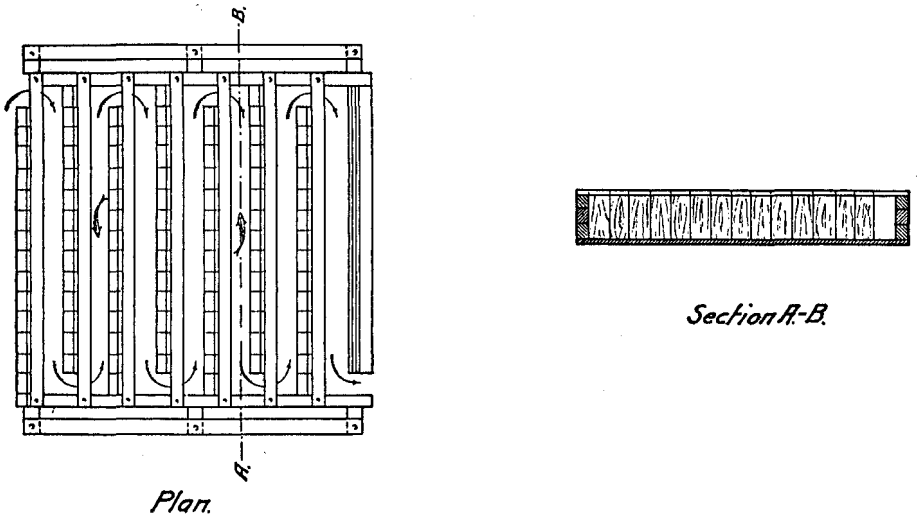


FIG. 3.—Wheeler.

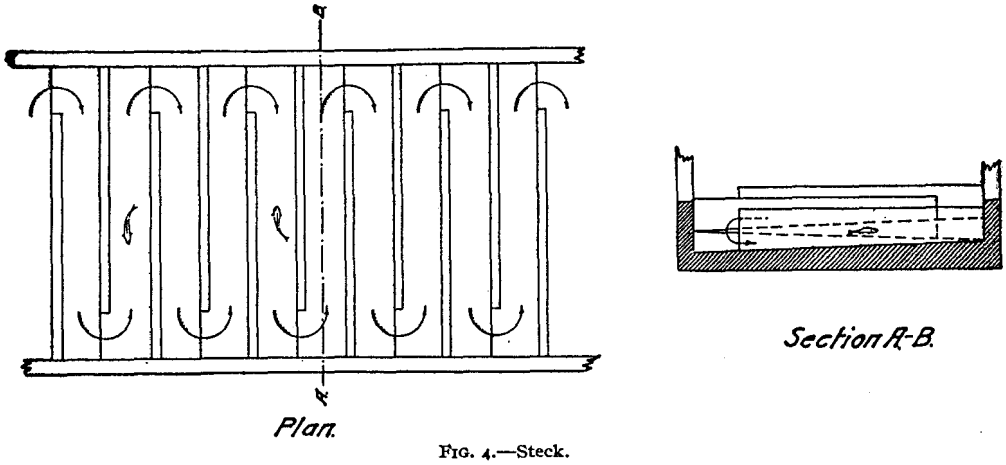


FIG. 4.—Steck.

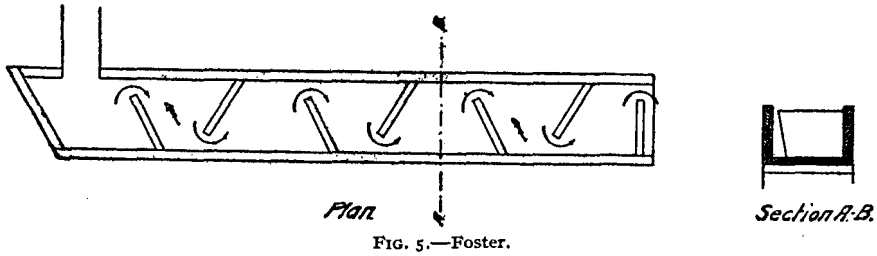


FIG. 5.—Foster.

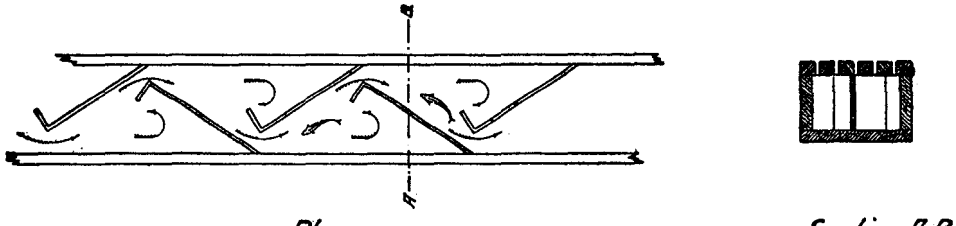


FIG. 6.—Rogers.

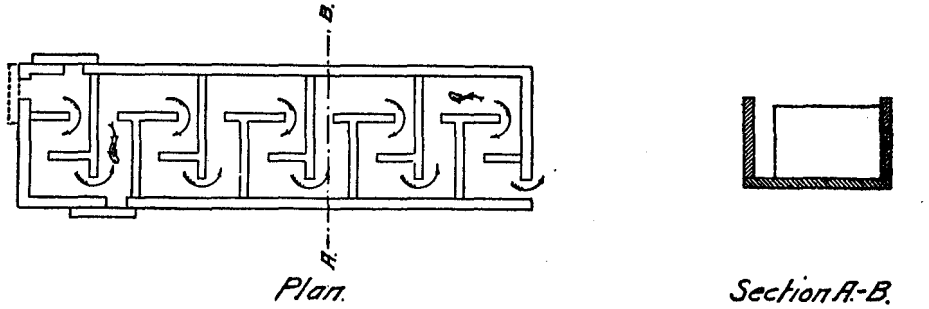


FIG. 7.—Brackett.

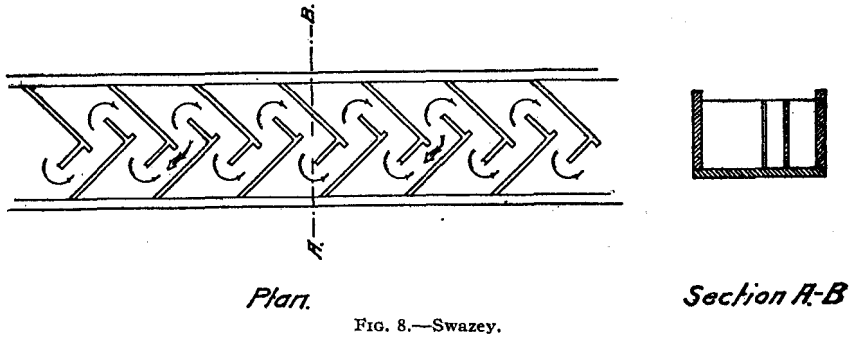


FIG. 8.—Swazey.

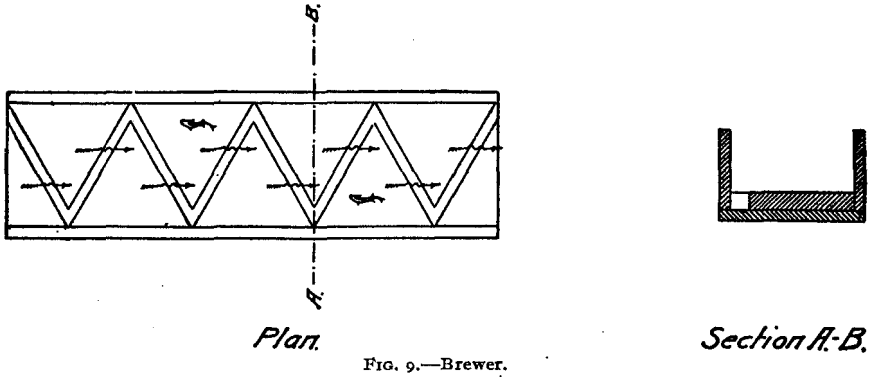


FIG. 9.—Brewer.

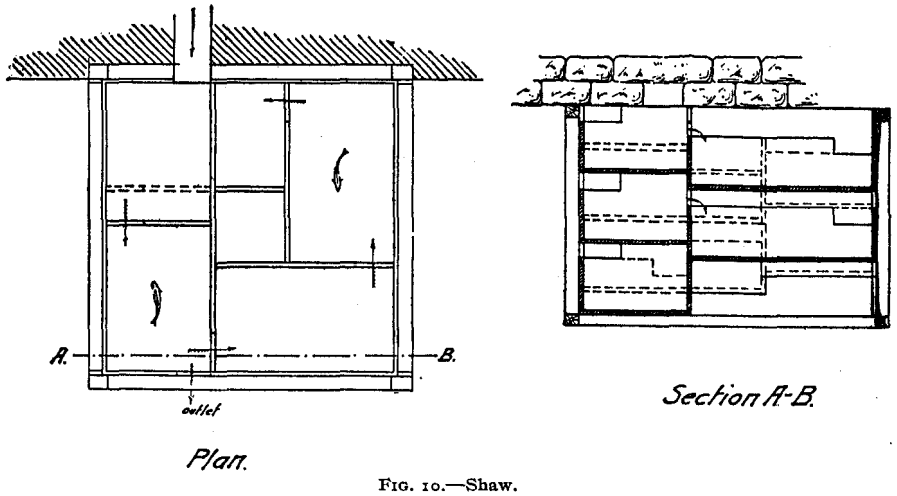


FIG. 10.—Shaw.

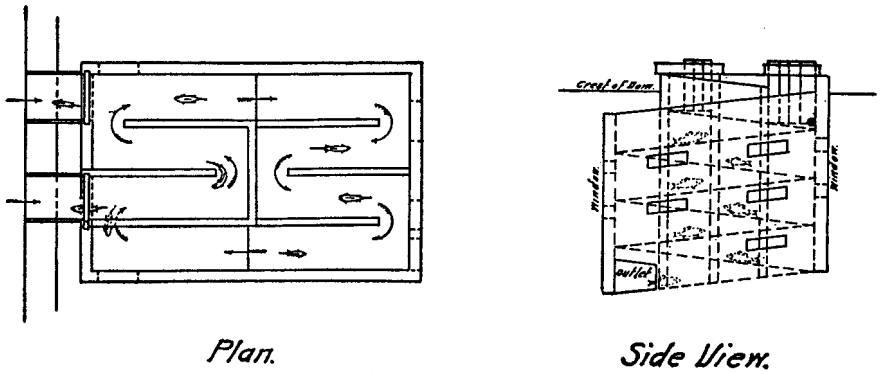


FIG. 11.—Atkins.

Under system 1 may be reckoned also the fishways for young eels, which consist merely of an inclined pipe from 4 to 6 inches in diameter, or a narrow flume, which is filled with loose gravel and pebbles, with fascines of brush and saplings, or with a mixture of both, through which the young eels can readily pass.

II. THE POOL AND FALL, OR STEP SYSTEM.

Figures 12 to 14 show the current carried down an incline broken by steps into a number of pools of relatively still water.

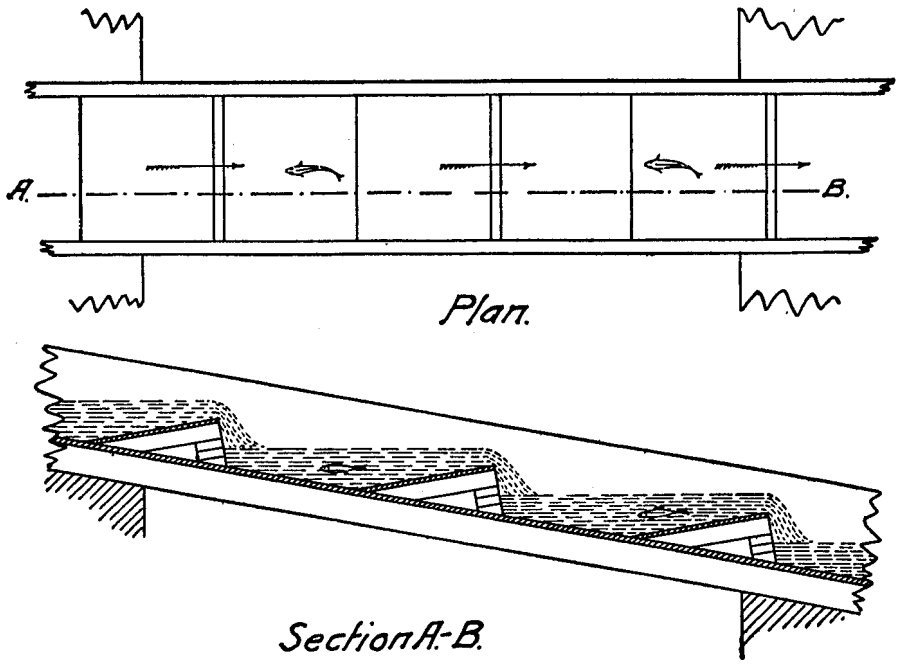


FIG. 12.—Richardson

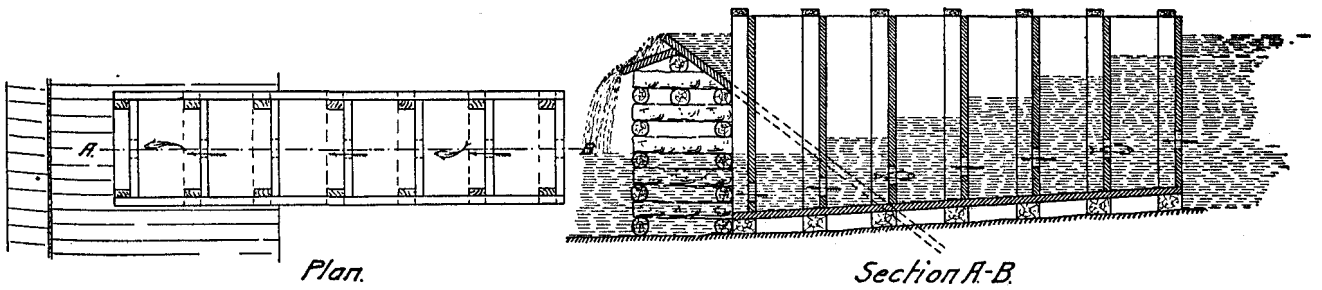
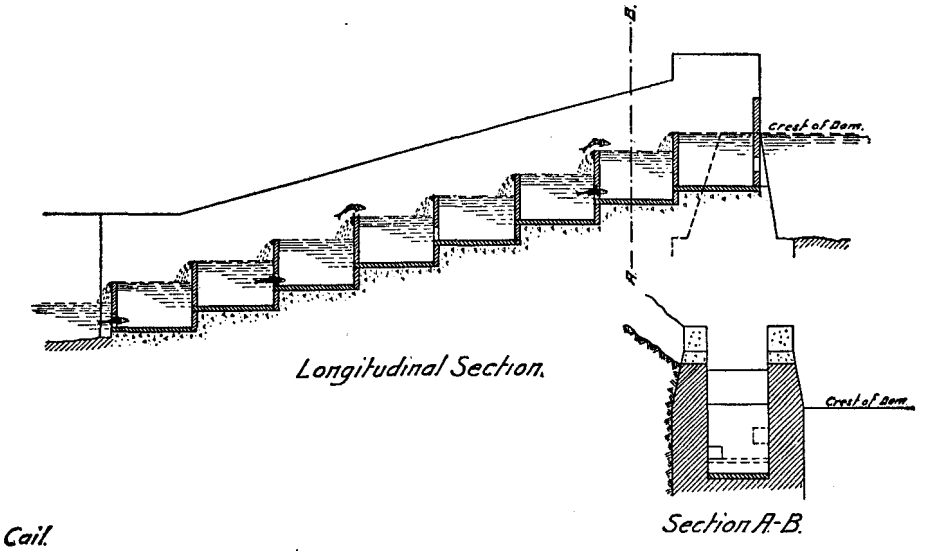


FIG. 13.—Hockin.



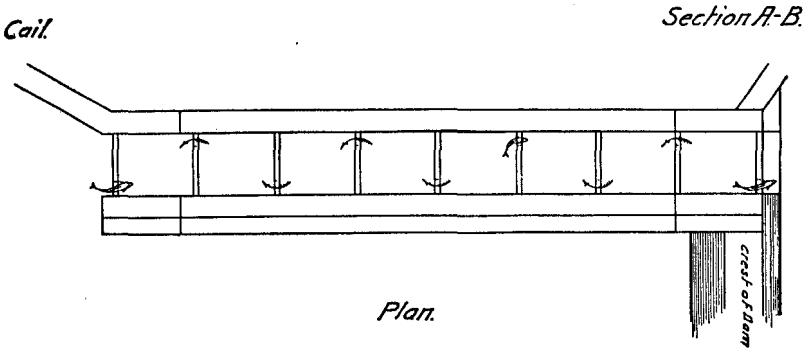


FIG. 14.—Cail.

III. THE COUNTERCURRENT SYSTEM.

Figures 15 to 17 show the action of a twofold current, the parts opposing each other and thereby retarding the velocity of the two combined.

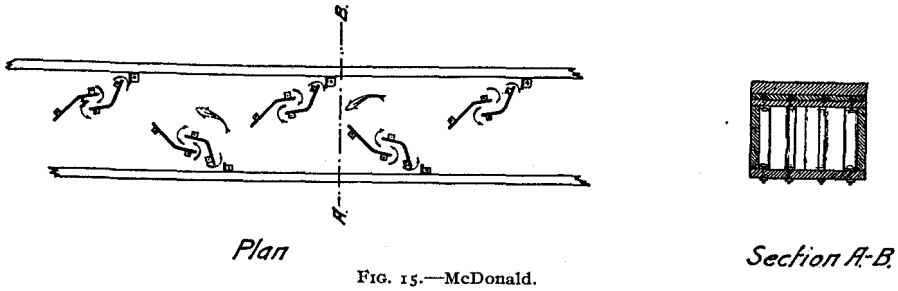


FIG. 15.—McDonald.

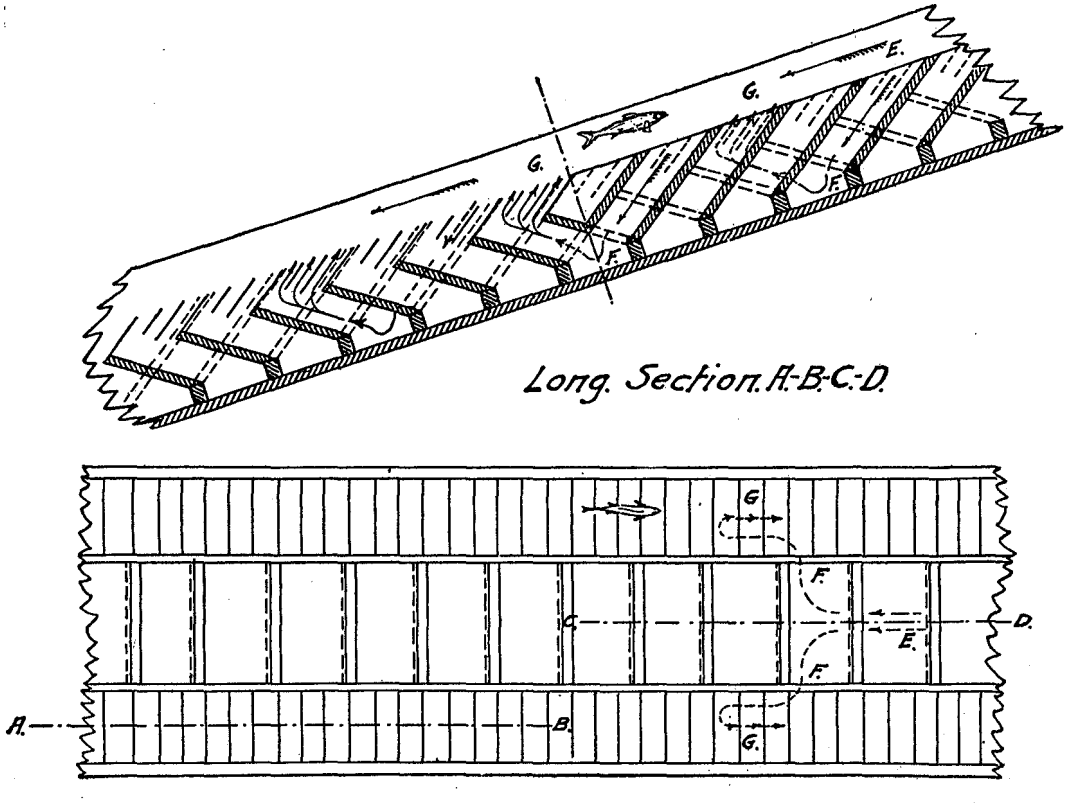


FIG. 16.—McDonald.

In this fishway the water passes through a series of centrally located buckets inclined downstream into another series of buckets located at either side of the fishway, provided on top with deflecting plates, whence it issues in an upstream direction, opposing the down current, as shown by arrows. The fishway may be protected by an iron grating over which the fish ascend.

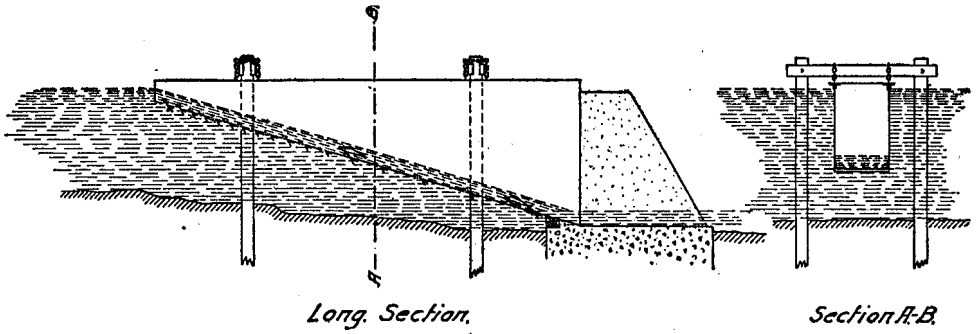


FIG. 17.—Caméré.

This fishway consists of a suitable chute submerged in the water as shown, and is provided with a series of slits in the bottom through which a current of water enters under a static pressure opposing the descending current of water in said chute. The design was later on improved by adding to the slits in the bottom a corresponding number of slits in the sides.

IV. LOCK AND GATE SYSTEM.

Figures 18 and 19 show the admission of a body of water by gates into a lock chamber and out of it to a lower level, whereby fish are being lifted vertically in ascending a stream.

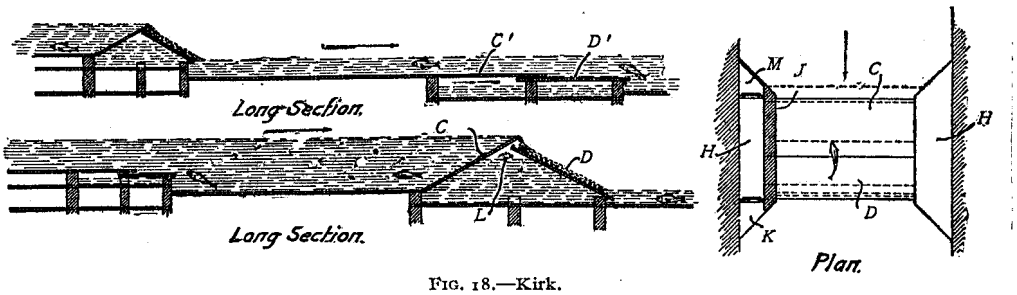


FIG. 18.—Kirk.

Process: If valve M is opened chamber HH will fill with water, and, by means of passageways under abutment J, the water will pass into chamber L and force gates CD to rise. The gates will rise until the water reaches an overflow opening at L. If valve M is closed and K opened, the water under the gates escapes and they will go down to position C' D'. Making the lower set of gates double the height of the upper set and arranging for an automatic alternate rising and lowering of the gates at certain intervals of time, the fish are enabled to pass upstream through these locks thus forming.

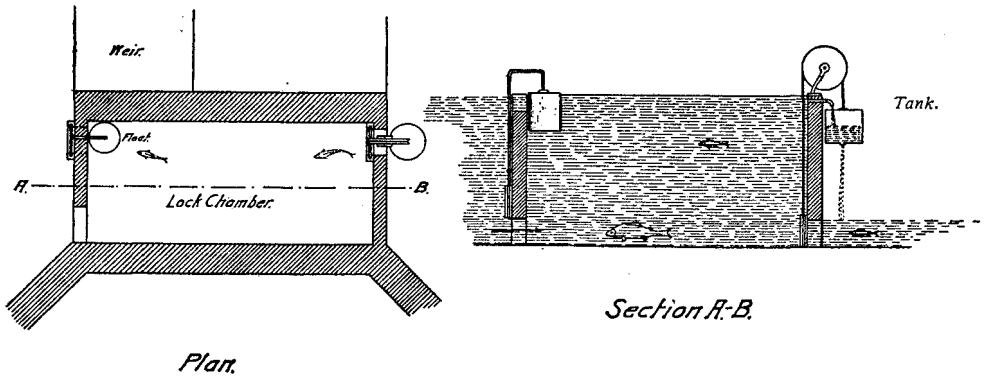


FIG. 19.—Recken.

Here the water chamber is shown full, and a water tank at the right is filling. When latter is full it will descend of its own weight and raise the gate, to which it is attached by means of a cable over a grooved wheel, allowing lock chamber to empty to lower level. When lock chamber is empty a float and gate in the upper partition, rigidly connected together, will be down; water tank being cut off from supply will also become empty, the water dripping gradually out of the bottom opening as shown. Supply through a notch in upper partition will begin to fill lock chamber and lift float and gate, thus repeating the process described.

THE IMPROVED CAIL FISHWAY.

The "Improved Cail fishway" (fig. 20) is a combination of the inclined plane system with the pool and fall or step system. It consists of a series of compartments arranged in steps and separated by a number of cross partitions, which are provided with suitable orifices at the bottom, alternating successively from side to side, so as to allow the fish, according to their individual habits, to ascend the fishway by either leaping over the small waterfalls over the cross partitions or by darting through the orifices, at the same time enabling them to rest in the compartments in comparatively still water.

The present improved Cail fishway embodies certain improvements made by B. M. Hoecht, of Germany, who built at Hameln, on the lower Weser, a large fishway on the Cail principle, constructing it of masonry and concrete, with a fall of about 1 foot in 8 feet. The design was brought to another form by the present author, and is now the pattern recommended by the United States Bureau of Fisheries. Its construction embraces all requirements for a fishway, as enumerated above, viz:

1. The slope of the fishway as per figure 20 is in a proportion of 1 vertical to 4 horizontal, the fall from compartment to compartment is 1 foot 6 inches, and the greatest velocity of the current through the orifices is less than 6 feet per second.

NOTE.—$V=m\sqrt{2gH}=0.57 \times 8 \times 1.23=5.6$ feet per second. V is the velocity in feet per second; g, acceleration per second of a falling body, 32.16 feet; H, head of water column proper, 1.5 feet; m, coefficient for contraction obtained by actual experiment, 0.57.

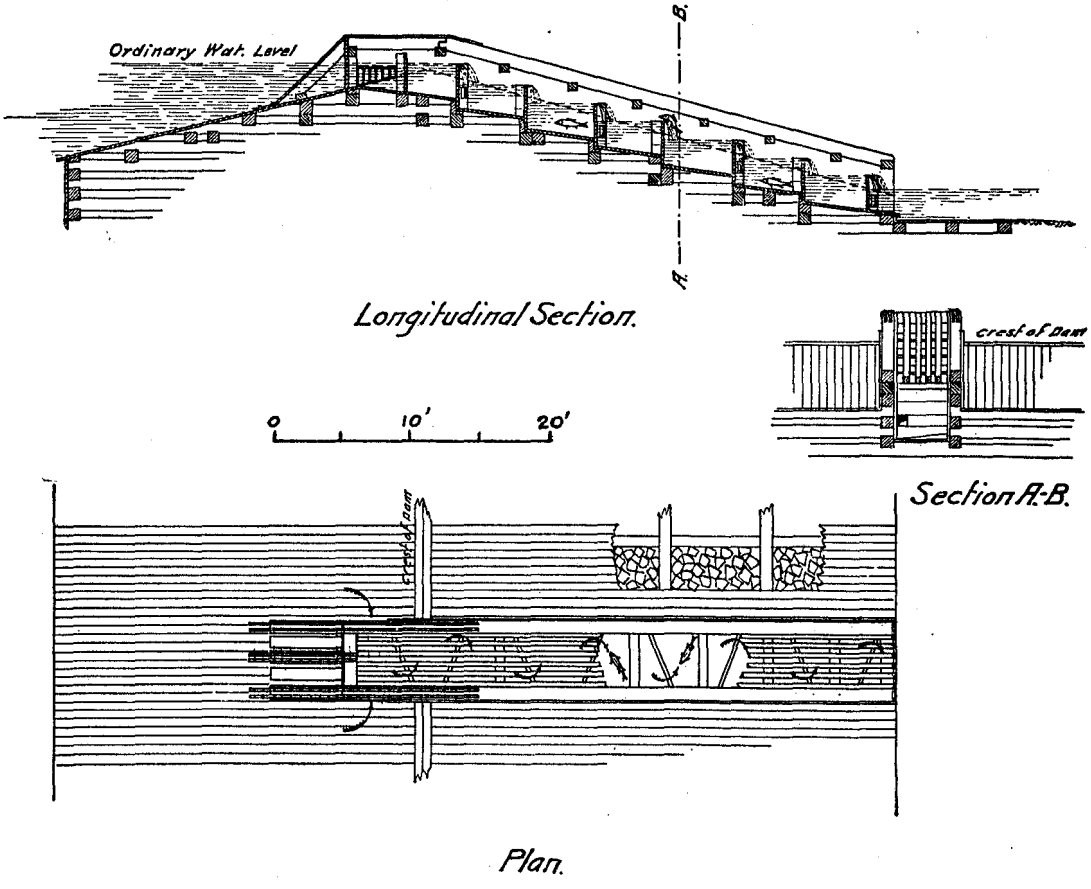


FIG. 20.—Improved Cail fishway.

2. The fishway proper is 4 feet wide inside, with orifices in the cross partitions varying from 12 inches by 12 inches at the outlet to 18 inches by 18 inches in the uppermost cross partition near the inlet, allowing fish of the size of shad, rockfish, salmon, etc., as well as smaller fish, to pass through.

3. The mean depth of water in the compartments is 3 feet.

4. Plenty of light is admitted through the open spaces between the protecting timbers on top, thus allowing ready inspection and easy removal of any débris lodging in the fishway.

5. The cross partitions are set at a slight angle to the axis of the fishway, and the floor of the fishway is slightly slanting, to bring the orifices in the lower ends of the cross partitions and cause a current in the angles formed between the cross partitions and the floor, thus automatically removing any accumulation of sand, gravel, mud, and rubbish.

6. The crest of the uppermost cross partition is at an elevation equal to that of ordinary high water, so as to keep the water supply in the fishway nearly the same at ordinary and high-water stage, avoiding thereby the need of any regulating gates.

7. The top and sides of the fishway are kept well above ordinary high water, to prevent the flooding of the fishway and possible injury.

8. Heavy timbers strongly bolted together are used in the construction of the sides and top of the fishway when built of wood, with strong fender pieces above the intake secured to the dam with heavy iron straps, to protect it against drift ice and logs during freshets.

9. Both the intake and the outlet are well submerged below mean water level, and the intake is protected against floating débris, etc., by a substantial iron grating.

The necessary volume of water for supplying a fishway of the dimensions as described here should not be less than 8 cubic feet per second.

The construction of the fishway is alike adapted to wood, masonry, or concrete, and it may follow either a straight line or have angles and returns, as the local conditions may require. The construction is applicable to the various forms of existing dams and natural waterfalls. The cost of construction of a fishway built of timber as per illustration under ordinary conditions will be about $1,000.

Fishways of this design have proved quite efficient and have been built in late years at various dams in the Susquehanna River and its tributaries; others, built of concrete, were constructed at a number of the large electric-light and power dams in several of the states. (See fig. 21, p. 1056–1057.)

REGULATIONS FOR THE CONSTRUCTION OF DAMS AND FISHWAYS.

The United States Government does not exercise any jurisdiction over waters not navigable, the construction of dams and fishways in these waters being regulated through the state laws. Most of the state legislatures have enacted such laws and fixed certain penalties for violation of the same. For navigable waters, an act of Congress approved June 21, 1906, to regulate the construction of dams provides as follows:

SECTION 1. That when, hereafter, authority is granted by Congress to any persons to construct and maintain a dam for water power or other purposes across any of the navigable waters of the United States, such dam shall not be built or commenced until the plans and specifications for its construction, together with such drawings of the proposed construction and such map of the proposed location as may be required for a full understanding of the subject, have been submitted to the Secretary of War and Chief of Engineers for their approval. * * * *Provided*, That in approving said plans and location such conditions and stipulations may be imposed as the Chief of Engineers and the Secretary of War may deem necessary to protect the present and future interests of the United States, which may include the condition that such persons shall construct, maintain, and operate, without expense to the United States, in connection with said dam and appurtenant works, a lock or locks, booms, sluices, or any other structures. * * *

SEC. 3. That the person, company, or corporation building, maintaining, or operating any dam and appurtenant works, under the provisions of this act, shall be liable for any damage that may be inflicted thereby upon private property, either by overflow or otherwise. The persons owning or operating any such dam shall maintain, at their own expense, such lights and other signals thereon and such fishways as the Secretary of Commerce and Labor shall prescribe.

SEC. 4. That all rights acquired under this act shall cease and be determined if the person, company, or corporation acquiring such rights shall at any time fail to comply with any of the provisions and requirements of the act, or with any of the stipulations and conditions that may be prescribed as aforesaid by the Chief of Engineers and the Secretary of War.

SEC. 5. That any persons who shall fail or refuse to comply with the lawful order of the Secretary of War and Chief of Engineers, made in accordance with the provisions of this act, shall be deemed guilty of a violation of this act, and any persons who shall be guilty of a violation of this act shall be deemed guilty of a misdemeanor and on conviction thereof shall be punished by a fine not exceeding five thousand dollars. * * *

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[a] Since this writing a most interesting article, "La genèse d'une échelle à poissons nouvelle," by G. Denil, has appeared in the Bulletin Populaire de la Pisciculture, no. 9, 1909, p. 155–183, Paris, 1909.

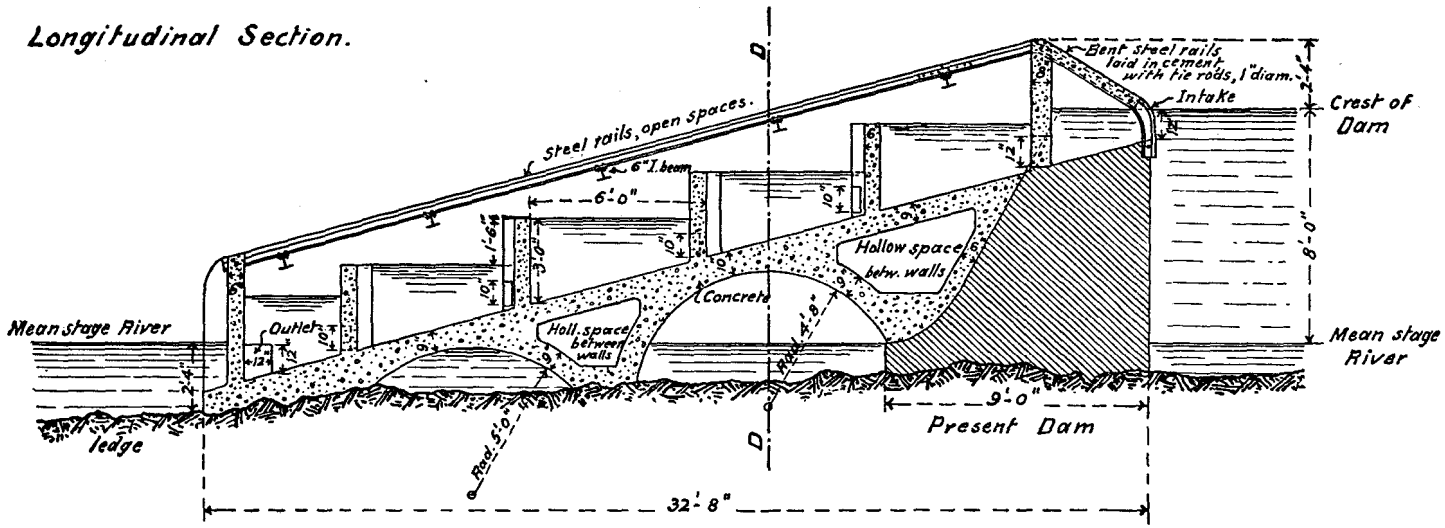

FIG. 21.—Adaptation of the improved Cail fishway, constructed of concrete. Designed by H. von Bayer for the Shenandoah River, in Virginia.

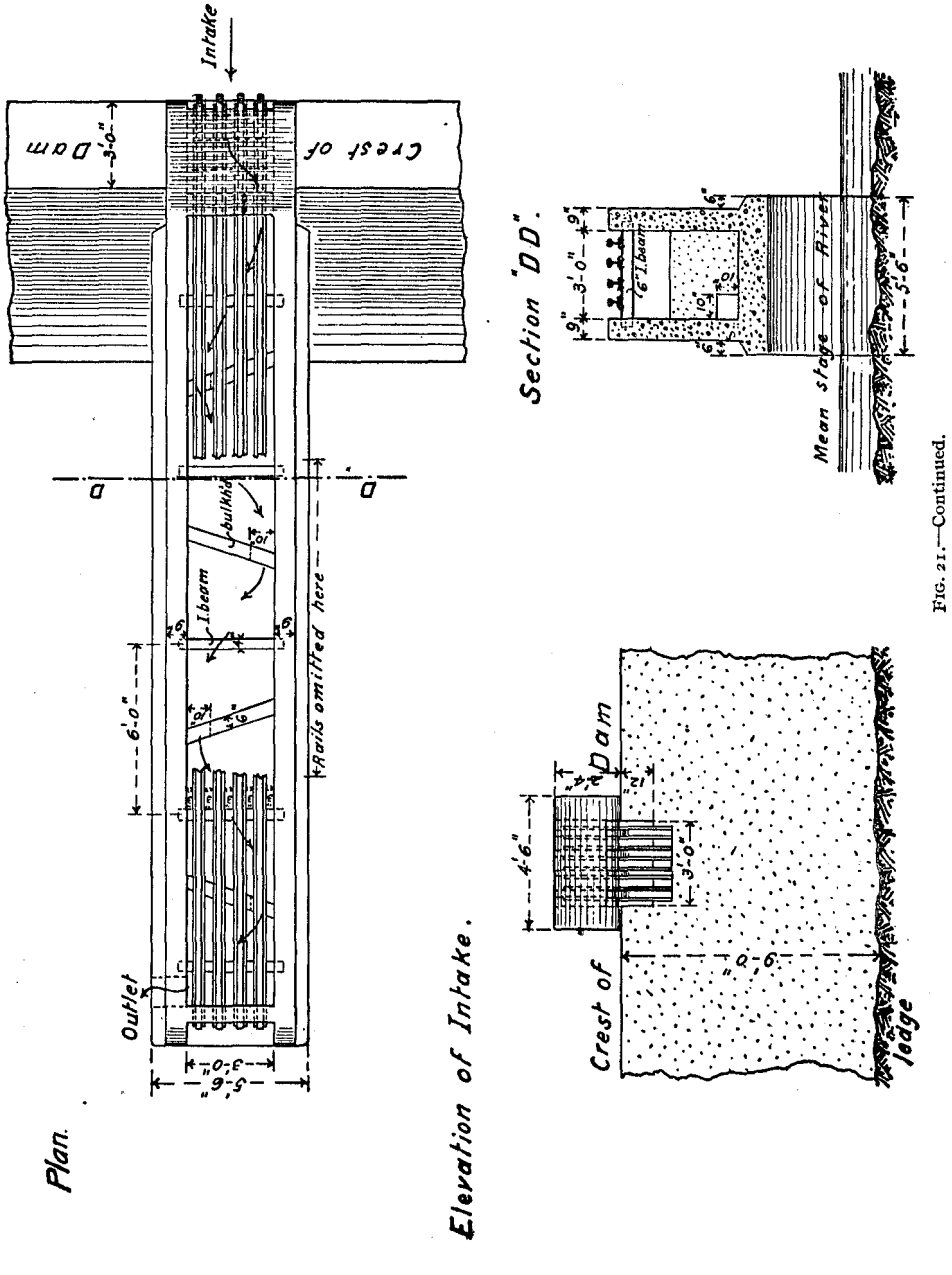

FIG. 21.—Continued.